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ABSTRACT

Idea-mapping (i-mapping), a way of representing ideas from a text in the form of a diagram, is defined and illustrated in this document as a way to help students "see" how the ideas they read are linked to each other. The first portion of the document discusses the fundamental relationships found in texts (A is a characteristic of B, A causes B) and how symbols are used in i-mapping to represent these relationships. This section also illustrates how an i-map succinctly represents the structure of a text, such as description, comparison and contrast, or definition and characteristics. The idea of frames and their corresponding frame i-maps are introduced as a way of representing repeating patterns of information in particular content areas: static frames capture the information associated with the general concepts of a subject matter area while dynamic frames represent repeated patterns of behavior or sequences of actions. The second section of the document discusses why i-mapping might be a useful instructional technique in reading as well as how teachers might implement the technique in the classroom. Several tables illustrating i-mapping are included, and appendixes contain three texts which the example i-maps represent. (HTH)

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CENTER FOR THE STUDY OF READING

Reading Education Report No. 36

IDEA-MAPPING: THE TECHNIQUE AND ITS USE IN THE CLASSROOM OR SIMULATING THE "UPS" AND "DOWNS" OF READING COMPREHENSION

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Idea-Mapping: The Technique and its Use in the Classroom
or
Simulating the "Ups" and "Downs" of Reading Comprehension

Idea-mapping (i-mapping) is a way of representing ideas from text in the form of a diagram. The symbols and shapes of i-maps show the types of relationships and organizational patterns in the text that the i-map represents. Therefore, we believe that i-maps can be useful to help students 'see" how the ideas they read are linked to each other. The purpose of this report is to define and illustrate the technique of i-mapping, and to suggest why and how i-mapping might be used in instructional settings.

The Technique

We think that the easiest way to understand i-mapping is to begin with a little exercise. Figure 1 is an i-map that is meant to represent the information given in an excerpt from a junior high science textbook. Begin by studying the i-map. Try to determine what the i-map means; that is, try to guess what information was presented in the textbook.

Insert Figure 1 about here.

The text that the i-map represents appears in Appendix A. This excerpt is the first few pages of a chapter entitled "Biomes." Now we suggest that you read the text and see whether your guesses about the meaning of the i-map are confirmed.

Having participated in this exercise, you're now ready for some more formal definitions. An i-map is a diagrammatic representation of information in text. The technique of i-mapping was designed specifically

to help students identify and learn about the ideas found in the informative text that they encounter in textbooks and other school-related materials.

A basic assumption of i-mapping is that many ideas in text are connected by a few fundamental relationships:

1. A is an instance of B
2. A is a property or characteristic of B
3. A defines B
4. A compares with B (that is, A is identical to, similar to, not similar to, greater than, or less than B)
5. A precedes B
6. A causes B
7. A enables B

Ideas are also related by the logical connectives and, or, and but. Each of these relationships between ideas is designated in text by certain standard words and phrases. For example, the A causes B relationship is designated by words such as "because," "since," "affects," "due to," and "therefore."

In i-mapping, a unique symbol stands for each of these basic relationships. For example, in the "Biomes" i-map, the symbol ⟹ stands for "causes"; in the tundra the ground is always frozen because of the year round cold climate. The symbol ≠ stands for "is different from"; the tundra differs from the taiga with respect to location, climate, and the plants and animals found there. The boxes embedded in boxes are "examples of"; oak and hickory are examples of deciduous trees. Table 1 contains a list of relationships and symbols used in i-mapping and some of the "key words" which signal these relationships in text. You will find it

helpful in trying to remember the symbols to look back at Figure 1 to find examples of the relationships and symbols illustrated in Table 1.

Note also, when studying Table 1, that the symbol X can be used to negate any relationship, although it is illustrated in Table 1 only with the "is similar to" and the "is an example of" relationships. Also, although i-mapping uses the logical relationships or, and, and but, only the use of or is illustrated; and and but are used analogously.

Insert Table 1 about here.

In addition to fundamental relationships connecting ideas in text, a few basic organizational patterns or text structures are commonly found in informative text. We call these content-free structures because they are found in texts on a variety of topics. Versions of these basic text structures have been identified in several sources (Herber, 1978; Niles, 1976; Meyer, 1979; Readance, Bean, & Baldwin, 1981). Our own version of what we will call Basic Text Structures is the following.

1. Description--a listing of properties, characteristics, or attributes where the order of presentation of the items is not significant.
2. Compare/contrast--a description of similarities and differences between two or more things.
3. Temporal sequence--a sequential relationship between ideas or events considered in terms of the passage of time.
4. Explanation--an interaction between at least two ideas or events, one the to-be-explained effect, and the other the reasons or causes for the effect.
5. Definition/examples--a concept is defined and examples of the concept are given.

We assume that each of these Basic Text Structures corresponds to a particular purpose or question that the author is addressing. For example, an author uses an Explanation text structure to answer the question "Why?" (sometimes "How?") and a Comparison/contrast text structure to answer the question "How are A and B alike and/or different?"

Each of these Basic Text Structures is represented by a unique i-map form. Table 2 presents the i-maps corresponding to each of the Basic Text Structures, as well as the author purposes or questions underlying each text structure. Note that these Basic Text Structure i-maps are built from the fundamental i-mapping relationships already introduced. The unique

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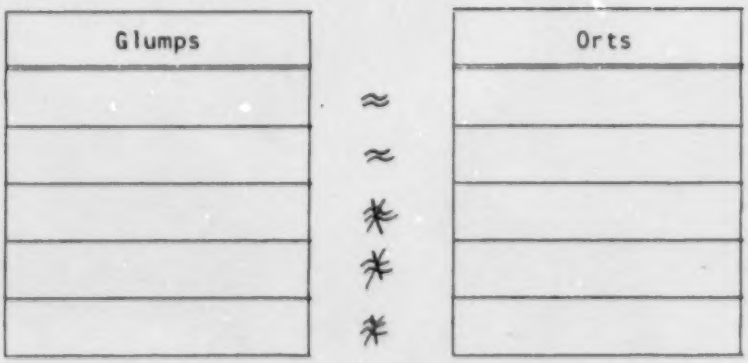
Insert Table 2 about here.

---

relationship between i-map forms and Basic Text Structures is important because a quick glance at an i-map can reveal the structure of the text and hence, the purpose or question the author is addressing. For example, one call tell a great deal about the text that the following i-map represents without even reading the text:



The author's purpose is to answer the question, "How are Glumps and Orts alike and different?" That is, the Basic Text Structure is Compare/contrast.

The author tells us five characteristics of both Glumps and Orts. Glumps and Orts have two similar characteristics and three different characteristics.

To give the reader a better feel for Basic Text Structures, Table 3 illustrates each of the Basic Text Structures and corresponding i-maps based on excerpts from real textbooks.

Insert Table 3 about here.

The excerpts in Table 3 represent relatively "pure" forms of Basic Text Structures. Most text, however, is made up of a combination of Basic Text Structures embedded one within another. Embedded text structures occur because the author often addresses several subquestions in order to answer one main question. For example, consider the "Biomes" i-map (Figure 1). Because we inferred that one of the author's main purposes was to answer the questions "How are the various biomes different from each other?" we used the Compare/contrast as a major text structure. In answering this compare/contrast question, the author addressed several subquestions, for example, "What is the climate of the tundra?" and "What are some examples of plants in the taiga?" In answering the latter question, the author addressed yet another subquestion: "What is the definition of an evergreen tree and what are some examples of evergreen trees?"

So far we've introduced the ideas of fundamental relationships in text and Basic Text Structures and shown how these can be uniquely represented in the form of i-maps. Now we turn to a new idea--a variation of Basic Text Structures which we think can be very useful to content-area teachers because the structures reflect the "main ideas" of the content being taught. This new type of text structure is called a <u>frame</u> (see also Armbruster &

Anderson, 1982, for more on frames). A frame is a Basic Text Structure that is adapted for use with a particular kind of content. Frames specify the "main ideas' or important information associated with a topic that is (or should be) included in a text dealing with that topic. For example, the "Biomes" i-map contains a frame for biomes. (Please look for the biomes frame in Figure 1 now.) The biomes frame is basically a Description Basic Text Structure with the characteristics or properties classified into categories: location, climate, plants, and animals. We chose to i-map these categories because we think that information on location, climate, plants, and animals are the "main ideas" or important information associated with a biome.

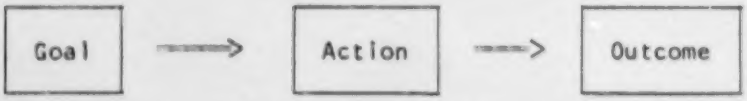
We recognize two types of frames: static and dynamic. The biomes frame is an example of a static frame. In general, a static frame is a Description Basic Text Structure with the characteristics or properties classified into categories called slots. The slots of a static frame are determined by the salient attributes or characteristics of the concept being described. For example, the slots of the biomes frame (location, climate, plants, animals) are deemed to be the salient characteristics of the concept "biome." Once the author had decided to define or describe biomes, he/she was obligated to present information pertinent to these slots.

Other examples of static frames appear in Figure 2. All of these static frames contain slots for types of important information about the topic that one might expect to find in text about that topic. These static frames were derived in a couple of different but complementary ways. One way was by knowing the definition of the concept--the attributes which

define the particular concept and make it distinctive from other concepts. The second way was by examining the way authors typically write about the concept. Authors seem consistently to include certain kinds of information when discussing the concept; these categories of information become the frame slots.

Insert Figure 2 about here.

Just as static frames are more specific versions of Description Basic Text Structures, so dynamic frames are more specific versions of Explanation Basic Text Structures. Dynamic frames thus include more information about the relationships among slots than do static frames. Since the idea of dynamic frames is most easily conveyed through an example, we'll begin with the example of a very general "goal" frame, which we believe can capture the "main ideas" associated with the explanation of an historical event. The Goal frame appears below.



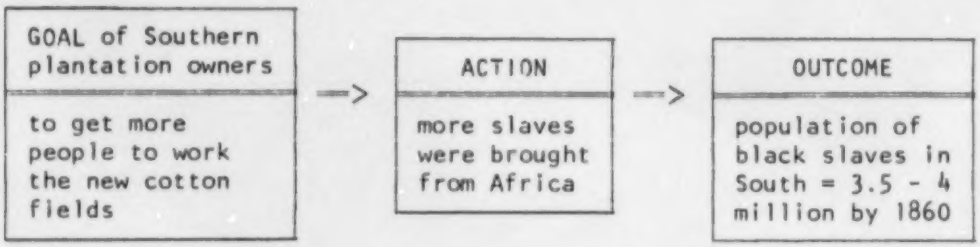
The Goal is the desired state sought by an individual or a group. The Action is the action taken to attain the Goal. The Outcome is the consequence of the Action, which may either satisfy or fail to satisfy the Goal.

Let's consider a short example of text for which the Goal frame might be appropriate:

> . . . the invention of the cotton gin in 1793 made slavery even more important to the South. The cotton gin separated cotton seeds from the fibers. This difficult job had been done by hand. The cotton gin thus made cotton an even more profitable crop.

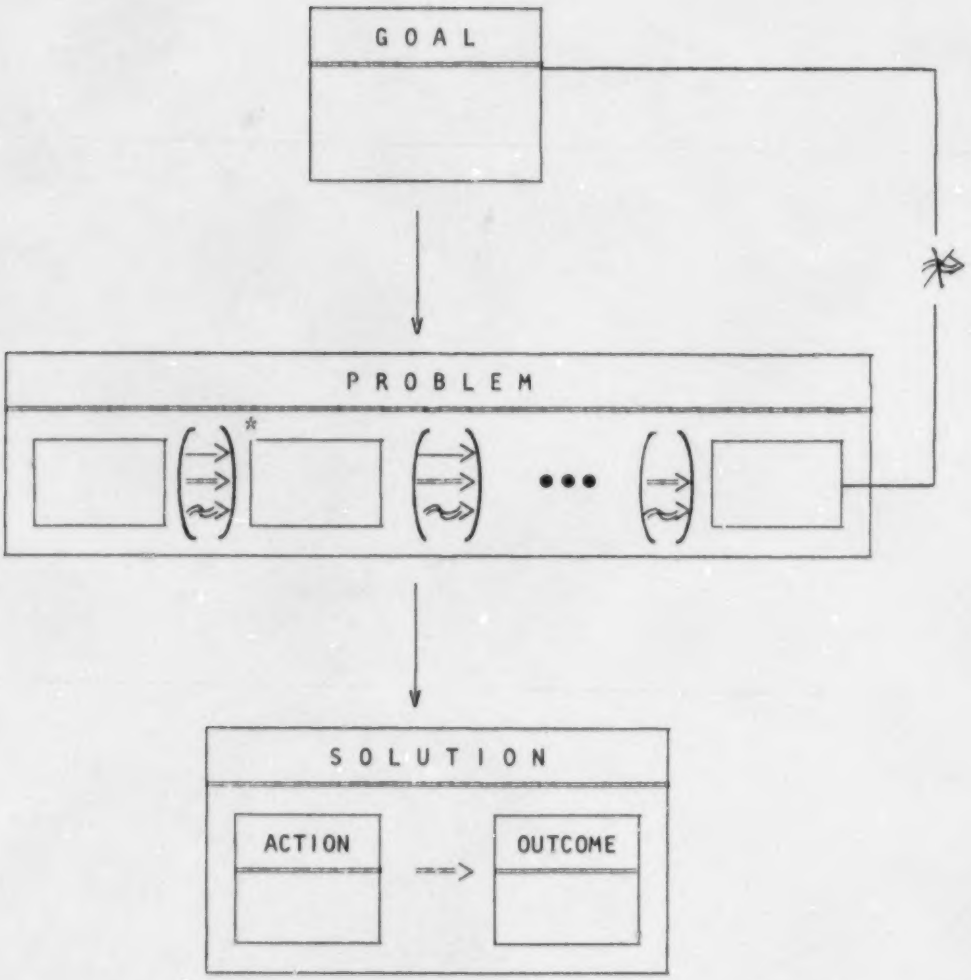
> More land was planted in cotton. More people were needed to work the new cotton fields. To fill the need, more slaves were brought from Africa . . . By 1860, there were about 3.5 to 4 million black slaves working in the South . . . (Abramowitz, p. 283)

Some of the information in that passage can be captured in the following Goal frame i-map.


GOAL of Southern plantation owners
to get more people to work the new cotton fields
ACTION
more slaves were brought from Africa
OUTCOME
population of black slaves in South = 3.5 - 4 million by 1860

One can easily think of many other examples of historical events that would fit the Goal frame: the search of Cortés for gold and silver and the subsequent conquest of the Aztec empire; the need for improved transportation to link the East and West and the building of the transcontinental railroad; Hitler's desire to preserve the "master race" of "Aryans" resulting in the murder of 6 million European Jews, and so on.

A variation of the dynamic Goal frame is another frame--the Problem/Solution frame. In this frame the Problem is an event, a condition, or a series of events or conditions resulting in a state that is an obstacle to the attainment of the Goal. The Problem prompts a Solution, which takes the form of the Action and Outcome of the Goal frame. The Outcome of the Solution either solves or fails to solve the Problem; that is, the Outcome either satisfies or fails to satisfy the Goal. The Problem/Solution frame i-map appears below.



* denotes that any of the three relationships may apply.

As an example of a text for which this frame is appropriate, consider typical accounts of "voyages of discovery." Such accounts usually begin with a statement of the Goal--the desire of Europeans for goods from the East, including silks and spices. The accounts go on to explain the problems of obtaining goods from the East. Here is the version from one textbook:

> The trade routes then in use presented several difficulties. Goods from the Far East (the part of Asia farthest from Europe) were transported the first part of the way by ship. Then they had to be unloaded and repacked on the backs of camels and donkeys for the overland trip to the Mediterranean Sea. There they were again reloaded by Italian merchants, who brought them to other parts of Europe. Each part of the journey was difficult and dangerous. The total amount of goods delivered each year was small. Because of the great risks and costs of unloading and reloading, prices were very high. (Schwartz & O'Connor, 1971)

The accounts of the voyages of discovery go on to talk about the Solution: the Action slot consisted of the actual voyages by various explorers, and the Outcome slot included the early disappointing outcomes of the quest for an all-water route, as well as the resulting discoveries of the explorers.

So far in this report we have defined and illustrated i-mapping as a diagrammatic representation of information in text. We introduced the symbols that stand for the fundamental relationships that connect ideas in text. Then we presented the i-map forms for each of the Basic Text Structures that are the building blocks of text. Finally, we introduced the idea of frames and their corresponding frame i-maps as a way of representing repeating patterns of information in particular content areas. Static frames capture the information associated with the general concepts of a subject matter area, while dynamic frames represent repeated patterns of behavior or sequences of actions. We have "discovered" many more static frames than dynamic frames, probably because the static frames are tied to specific concepts, while the dynamic frames are general enough to apply to a wide range of content.

The next section discusses <u>why</u> i-mapping might be a useful instructional technique in reading as well as <u>how</u> teachers might implement the technique.

Using I-Mapping in Instruction

Why Use I-Mapping in Instruction?

In another report (Armbruster & Anderson, 1980), we presented a research-based rationale for the instructional use of i-mapping: i.e., involvement of students with the meaning of the text, attention to text structure, and transformation of prose into a diagrammatic or visual representation. In this report, we turn to a more theoretical rationale for the use of i-mapping in the classroom, based on the currently popular schema theory of reading comprehension.

According to schema theory, a reader's schema, or organized knowledge of the world, provides the basis for comprehending, learning, and remembering information in text. Comprehension occurs when the reader activates or constructs a schema that explains events and objects described in a text. As readers first begin to read, they search for a schema to account for the information in the text, and on the basis of the schema, they construct a partial model of the meaning of the text. The model then provides a framework for continuing the search through the text. The model is progressively refined as the reader gathers more information from the text. Reading comprehension, according to this view, thus involves the progressive focusing and refinement of a complete, plausible, and coherent model of the meaning of the text.

A further refinement of schema theory is that the processing of information in the text proceeds in two basic modes: bottom-up and top-down. Bottom-up, or data-driven, processing proceeds from lower to higher levels of linguistic analysis. The processing begins with an analysis of letter features, combines words to construct meanings of phrases and sentences, and so on through increasingly comprehensive levels of interpretation and

integration. Bottom-up processing starts from the lowest level schemata and gradually builds higher-order schemata.

Top-down, or conceptually-driven, processing proceeds in the opposite direction. Based on some minimal knowledge of the text (for example, a title, illustration, or topic sentence), the reader forms an expectation or hypothesis about the meaning of the text. Reading then consists of a search for information either to support or refute the hypothesis. That is, the reader first activates higher-order schemata and then seeks information in the text to fit the schemata.

In schema theoretic accounts of reading comprehension, text processing involves both top-down and bottom-up processing simultaneously. That is, through bottom-up processing the reader finds the information needed to fill out the higher-order schemata; through top-down processing the reader can find and assimilate information in an efficient manner (Adams & Collins, 1977).

We argue that constructing an i-map of a text is roughly analogous to constructing a coherent model of the meaning of the text, involving both bottom-up and top-down processes. Therefore, we see i-mapping as a tool that teachers and students can use to build a model of text meaning, with the finished i-map as a visual representation analogous to the thought process that the students might be expected to have experienced if they read and interpreted the text.

How Can I-Mapping be Used in Instruction?

With the use of i-maps, teachers can help students to better understand their texts using both top-down and bottom-up strategies. We will illustrate how this might be done, starting with top-down processing. Remember that

in top-down processing, the reader formulates an expectation about the meaning of the text and then seeks information in the text to support the expectation. To simulate top-down processing, the teacher could begin by providing students with such an "expectation" or "higher-order schema" prior to a reading assignment. This "higher-order schema" could be in the form of what we'll call a "main idea" map. For example, a teacher about to assign the chapter on biomes could begin by giving students the static frame i-map for biomes:

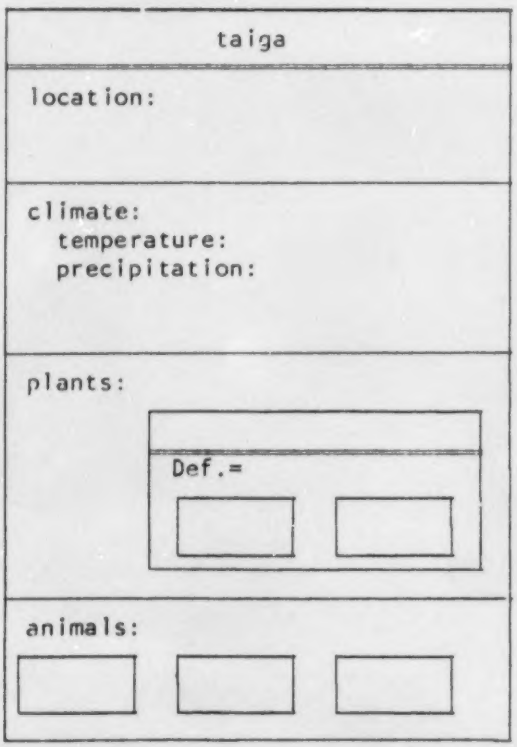
biomes
location:
climate: temperature: precipitation:
plants:
animals:

This static frame represents the expectation or higher-order schema that a reader knowledgeable about the concept of biomes would probably bring to the text.

The teacher could use the "main idea" i-map in two ways: (a) As the basis for a recommended processing aid. That is, the teacher could suggest that students might use the "main idea" i-map as a framework for organizing and assimilating information as they read. (b) As the basis for a product,

or student exercise, that would be an index of student understanding of the text. In more conventional terms, these exercises require students to find details in support of a main idea.

As an example of the latter, the teacher could ask students to fill out a biome frame map for each biome in the chapter. The teacher could further constrain the task by using i-mapping symbols to specify the exact type of information students should supply, as in the following example:



In this example, the form of the i-map tells students that they need to provide the definition and two examples of a type of taiga plant and that they need to find three examples of animals that live in the taiga.

We will give another example of top-down i-mapping using the passage from a fifth grade social studies textbook that appears in Appendix B.

We think fifth grade readers will find this text difficult to understand and remember. We believe that the author's purpose was probably to explain the principle that location has a significant effect on where cities are established and whether or not they will grow. Instead of stating the principle, however, the author has chosen to given examples of it. Fifth grade readers are unlikely to be able to infer the principle from these examples, at least not without assistance. We think it would help students to read the passage with understanding if the teacher familiarized them with a "main idea" map which represented the principle prior to reading the passage. The i-map might look like this:

This "main idea" i-map could serve as a guide for how students should think about the text or it could serve as the basis for a student exercise. More structured versions of the exercise appear in Figure 3.

Insert Figure 3 about here.

As illustrated by these examples, teachers can encourage students to engage in top-down processing by helping them to generate a higher-order schema in the form of a "main idea" i-map. Students can do the top-down processing "in their heads" or demonstrate that they have engaged in top-down processing by completing written i-mapping exercises.

Now we will describe how teachers can use i-mapping to encourage bottom-up processing. Remember that in bottom-up processing, the reader constructs a higher-order schema for the text's meaning from lower-order elements of the text. To simulate bottom-up processing, the teacher could

use i-mapping to help students derive higher-order structures. In more conventional terms, the teacher would be guiding the students to make generalizations, to induce principles, or to discover main ideas.

For example, the bottom-up exercise in Figure 4 might be used with the chapter on biomes. This exercise encourages students to infer the labels for the slots of the biome frame from a couple of examples. We think that the visual display will help students see common patterns that they might have difficulty inferring from text alone.

Insert Figure 4 about here.

To repeat, in our opinion, one problem with the "More Cities Grow" passage was the lack of an explicit statement of the principle that location influences the establishment and growth of cities. Rather than giving students this principle, however, the teacher may prefer to have the students induce the principle themselves. The bottom-up exercises presented in Figure 5 could help. Note that these exercises are simply

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Insert Figure 5 about here.

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the converse of the top-down exercises. In this case, students are given details from the text and are guided by the form of the map to make a particular type of generalization.

Another form of bottom-up exercise will be illustrated using the text on honeybees that appears in Appendix C.

One of many possible bottom-up exercises to accompnay this text is presented in Figure 6. Students are given a list of key terms from the reading assignment. They are asked to construct an i-map that incorporates

all of the terms. In this case, it is left to the students to induce an appropriate structure from the text.

Insert Figure 6 about here.

Incidentally, we believe that the type of exercise illustrated in Figure 6 may be an especially valuable tool for helping students learn new vocabulary. We think that trying to place a new word in one or more meaningful relationships to other words is a much more effective vocabulary-learning strategy than the common strategy of looking up the definition in the glossary and using the word in a sentence. Students can look up words and copy sentences without understanding or learning a thing. But the student who has correctly i-mapped grub as being one of four examples of a life stage of honeybees, the state after egg and before pupa, and equivalent to larva has learned a great deal indeed about grubs (without grubbing around in a dictionary!).

As illustrated in the examples above, teachers can encourage bottom-up processing by providing i-mapping exercises that guide students to induce higher-order structures or "main idea" organizers for the information in text. Many different kinds of bottom-up exercises can be constructed, varying in the prompting given or degree of generalization required.

In order to use top-down and bottom-up i-mapping exercises to help students read and learn from text, of course, the teacher has to study the text carefully and construct an appropriate organization for the information in the text. If the structure is not clear from the text (and it often isn't), the teacher may have to fill in missing or vague information by inducing an acceptable frame as we did with the biome text, or an appropriate

main idea or principle, as we did with the "More Cities Grow" text. We think that this stage of constructing the exercises will give teachers new insights about the higher-order organization of the ideas the students are expected to learn.

Once the higher-order structure has been derived, the final form of the exercises is limited only by the teacher's imagination. The examples presented in this report only begin to suggest the creative possibilities of i-mapping in the classroom. Please write and tell us about other ones that you come up with, and we'll try to pass the ideas along.

Of course, in order to use i-mapping exercises, the students also have to know the i-mapping technique--the symbols standing for relationships in text, the Basic Text Structures, and the fact that information is often presented in repeatable patterns. We think that just teaching students this basic information about text would help them a great deal in reading and learning from their textbooks, even if they never saw an i-mapping exercise.

In sum, i-mapping provides a tool for constructing exercises that can guide students' comprehension of text and help them develop a coherent model of the meaning of the text. We think that both top-down and bottom-up kinds of i-mapping exercises, given that they are carefully constructed, could be a valuable asset to instruction, particularly in developing reading skills for informative, content-area text.

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Table 1

Relationships and Symbols Used in I-Mapping

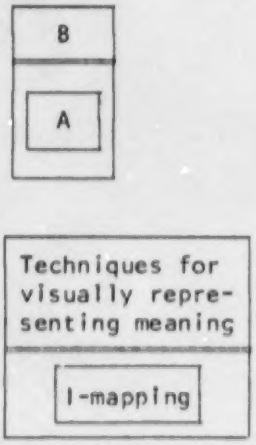
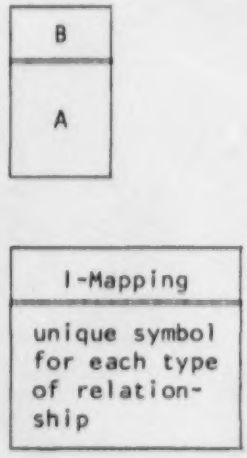
		Key Words
(1) A is an instance of B. Example: I-mapping is one of several techniques for visually representing meaning.		to be, for example, for instance, type of, kind of, example of, e.g., such as, include, including
(2) A is a property of B. Example: I-mapping has a unique symbol for each type of relationship.		(to be), (to have), is a property of, is a feature of, is a characteristic of, is a part of,

Table 1 (Cont'd)

	Key Words
(3) A defines (restates, clarifies) B. B DEF. = A Example: Biomes are large areas that have similar communities of plants and animals. Biomes DEF. = large areas that have similar communities of plants and animals.	that is, in other words, i.e., (to be), is named, is called, is defined as, is referred to as, is labelled, means that, the definition is
(4) A is identical to B. A ≡ B Example: The i-mapping symbol for "is an instance of" is a Venn diagram. Mapping symbol for "is an instance of" ≡ Venn diagram	is, is identical to, is the same as, is known as
(5) A is similar to B. A ≈ B Example: Compare/contrast i-maps are similar to double-entry tables. Compare-contrast i-maps ≈ double-entry tables	like, likewise, is similar, similarly, in the same way or manner

Table 1 (Cont'd)

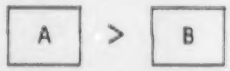
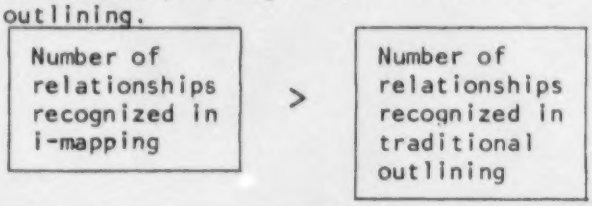
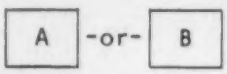
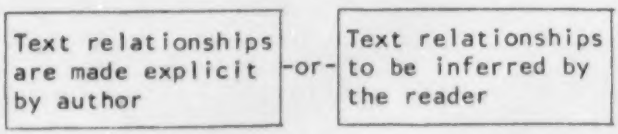
(6) A is not similar to B. Example: I-mapping is different from outlining. 	Key Words is different from, is not the same as
(7) A is greater than B.  A is less than B. Example: The number of relationships recognized in i-mapping is greater than the number of relationships recognized in traditional outlining.  	more, greater, larger, less, smaller
(8) A or B.  Example: Relationships in text are either made explicit by the author or left to be inferred by the reader.  	or, either the one or the other

Table 1 (Cont'd)

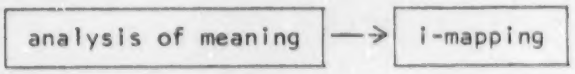
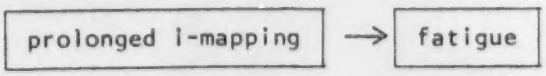
	Key Words
(9) A occurs before B. Example: Analysis of meaning precedes i-mapping. 	then, and then, before, after, next, follows, earlier, later, previously, prior, subsequently, precedes, (dates), first, second, third
(10) A causes B. Example: Prolonged i-mapping produces fatigue. 	brings about, results in, causes, affects, leads to, in order to, produces, therefore, because, since, as a result of, this is because, consequently

Table 1 (Cont'd)

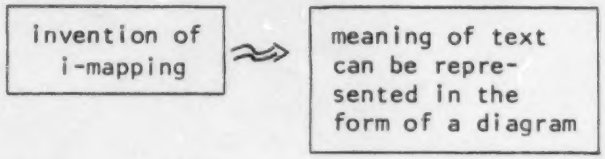
	Key Words
(11) A enables B. Example: I-mapping was invented so that the meaning of text could be represented in the form of a diagram. 	enables, allows, permits, so that

Table 2

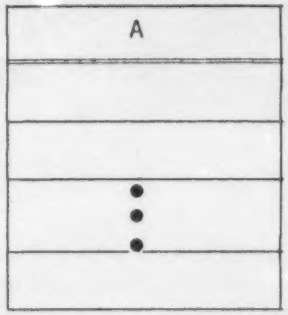
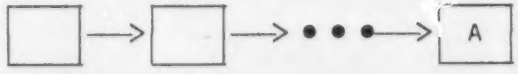
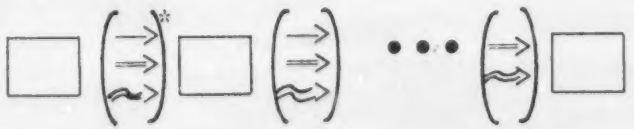
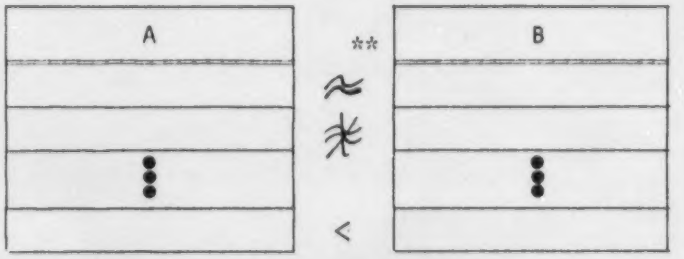
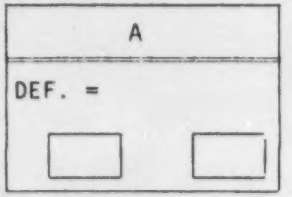
Examples of Author Purposes or Questions		Basic Text Structures	Basic Text Structure I-maps
Imperative Form	Interrogative Form		
Define A.	What is A?	Descriptions	
Describe A.	Who is A?		
List the features/ characteristics/ traits of A.	Where is A?		
Trace the development of A.	When did A occur (in relationship to other events)?	Temporal Sequences (Processes, Procedures, Chronologies)	
Give the steps in A.			
Explain A.	Why did A happen?	Explanations	
Explain the cause(s) of A.	How did A happen?		
Explain the effect(s) of A.	What are the causes/ reasons for/effects/ outcomes/results of A?		
Draw a conclusion about A.			

Table 2 (Cont'd)

Examples of Author Purposes or Questions		Basic Text Structure	Basic Text Structure i-map
Imperative Form	Interrogative Form		
Predict what will happen to A. Hypothesize about the cause of A.	What will be the effects/outcomes/ results of A?		
Compare and contrast A and B. List the similarities and differences between A and B.	How are A and B alike and/or different?	Compare/Contrast	
Define and give examples of A.	What is A, and what are some examples of A?	Definitions/Examples	

* denotes that any of the three relationships may apply.

** Any of the relationships of comparison ($\approx$, $\not\approx$, $<$, $>$, $\equiv$) might apply.

Table 3

Examples of Text Units and Corresponding Unit Maps

Description

Batholiths are the largest igneous rock bodies. They may form several kilometers below the surface of the earth. They are 50 to 80 kilometers across and extend for hundreds of kilometers in length. Batholiths are too thick for their lower surfaces to be seen. They are exposed at the earth's surface only when the overlying rock has been removed by erosion. Most batholiths are great masses of granite. They form the cores of the world's mountain systems.
(Bishop, M. S., Sutherland, B., & Lewis, P. G. Focus on earth science. Columbus, Ohio: Charles E. Merrill, 1981, p. 330)

B a t h o l i t h s
largest igneous rock bodies
may form several kilometers below the surface of the earth
50-80 kilometers across
extend for hundreds of kilometers in length
too thick for lower surfaces to be seen
exposed at earth's surface only when overlying rock has been removed by erosion
most are great masses of granite
form the cores of world's mountain systems

Table 3 (Cont'd)

Temporal Sequence

The iron ore in the ground is usually covered with a thick layer of dirt and rock. This layer must be removed before the actual mining can begin. After the dirt is taken away, huge power-driven shovels dig into the crumbly iron ore. The shovels carry load after load of ore from the pits to railroad cars that are standing nearby.

When a long line of cars is filled, the cars are attached to a locomotive. These trains take the ore to boats that are waiting at nearby ports on the Great Lakes. The boats then take the ore to steel mills that are located on or near other Great Lakes ports.

(Gross, H. H., Follett, D. W., Gabler, R. E., Burton, W. L., & Ahlschwede, B. F. Exploring Our World: The Americas. Chicago: Follett, 1980, p. 224)

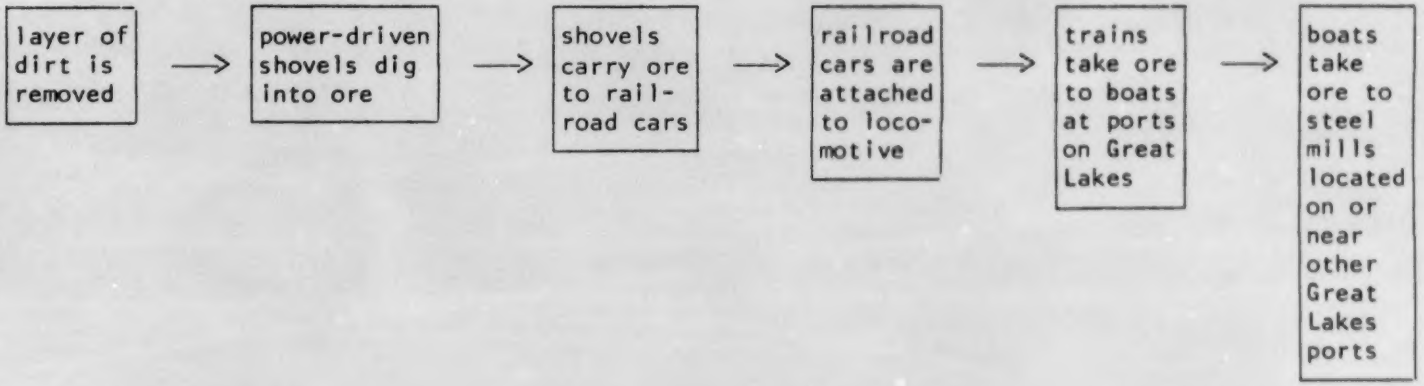

layer of dirt is removed
power-driven shovels dig into ore
shovels carry ore to rail-road cars
railroad cars are attached to loco-motive
trains take ore to boats at ports on Great Lakes
boats take ore to steel mills located on or near other Great Lakes ports

Table 3 (Cont'd)

Explanation

In cold or mountainous regions, rocks are often subjected to the action of freezing water because of daily changes in the temperature. During the day, when the temperature is above the freezing point of water (0°C), rainwater or melted snow or ice trickles into cracks in the rocks. During the night, when the temperature falls near the freezing point of water, the trapped water expands as it changes into ice.

As freezing water expands, the expanding ice pushes against the sides of the cracks with tremendous force, splitting the rocks apart. In this way, large masses of rock, especially the exposed rocks on the topics of mountains, are broken into smaller pieces. . . .

(Lesser, M., Constant, C., & Wisler, J. J. Contemporary Science Book 1. New York: Amsco School Publications, Inc., 1977, pp. 282-283)

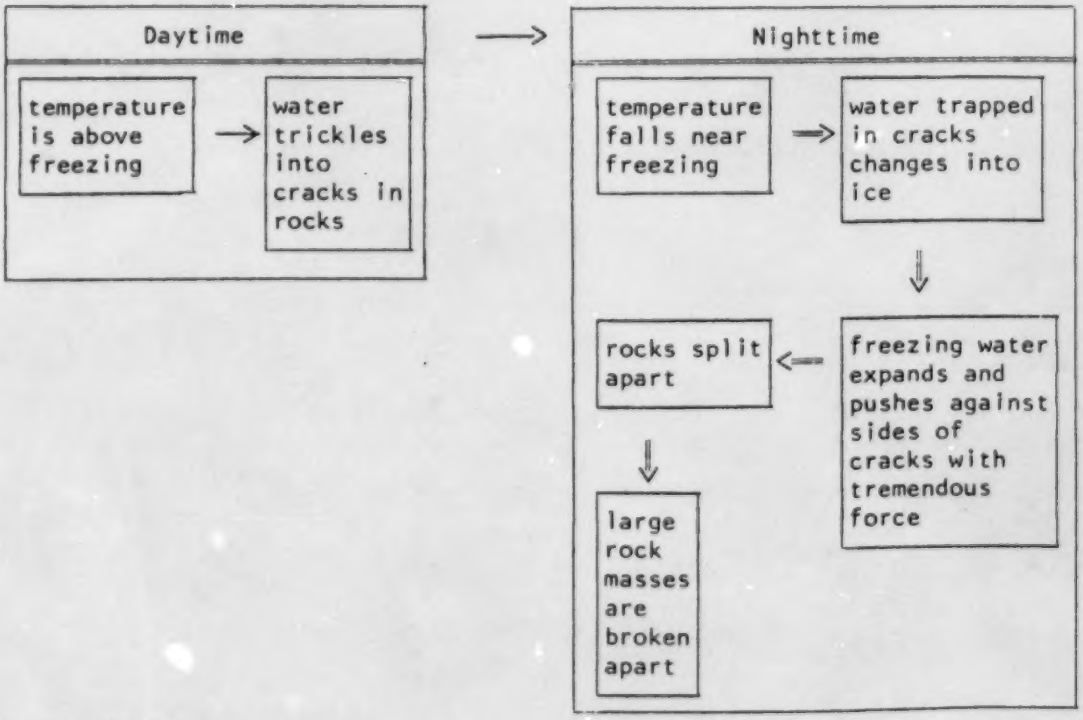

Daytime
temperature is above freezing
water trickles into cracks in rocks
Nighttime
temperature falls near freezing
water trapped in cracks changes into ice
freezing water expands and pushes against sides of cracks with tremendous force
rocks split apart
large rock masses are broken apart

Table 3 (Cont'd)

Compare/Contrast

Body waves are of two kinds. The P-wave, or primary wave, travels foward in a horizontal direction. Rock particles vibrate back and forth. They are pushed close together, then move apart to their original positions. A slinky toy, held at one end, then given a slight jerk, shows the P-wave motion. The S-wave or secondary wave, vibrates at right angles to the P-wave. Particles move up and down, but the wave itself travels forward. The S-wave motion is like that of a rope fixed at one end and moved up and down at the free end.

(Bishop, M. S., Sutherland, B., & Lewis, P. G. Focus on earth science. Columbus, Ohio: Charles E. Merrill, 1981, p. 292)

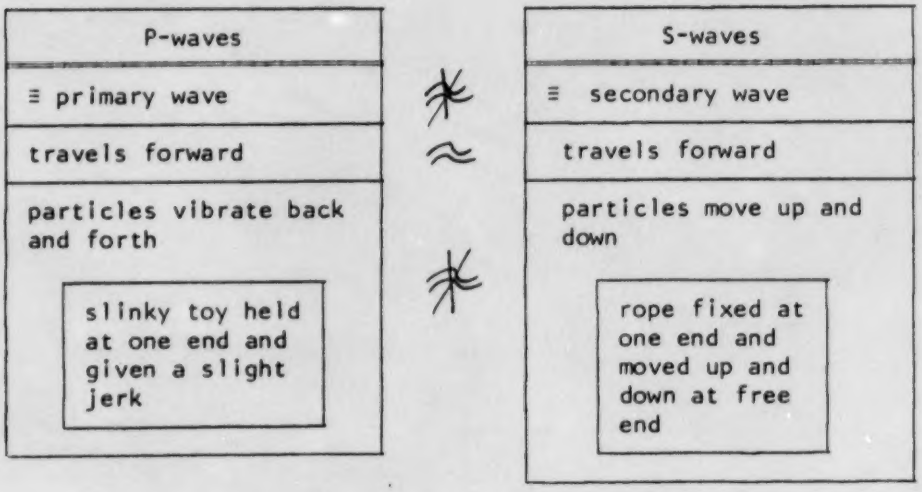

P-waves
≡ primary wave
travels forward
particles vibrate back and forth
slinky toy held at one end and given a slight jerk
S-waves
≡ secondary wave
travels forward
particles move up and down
rope fixed at one end and moved up and down at free end

Table 3 (Cont'd)

Definition--Example

In this forest biome, you would notice many deciduous trees. Deciduous trees grow leaves in the spring which fall from the trees in autumn. Oak, hickory, beech, and maple are deciduous trees.

(Sund, R. B., Adams, D. K., & Hackett, J. K. Accent on science. Columbus, Ohio: Charles E. Merrill, 1980, p. 142)

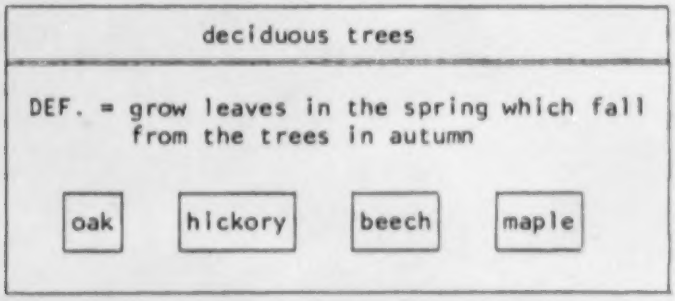


Figure Captions

Figure 1. Idea-map of information from a chapter entitled "Biomes" in a junior high science textbook.

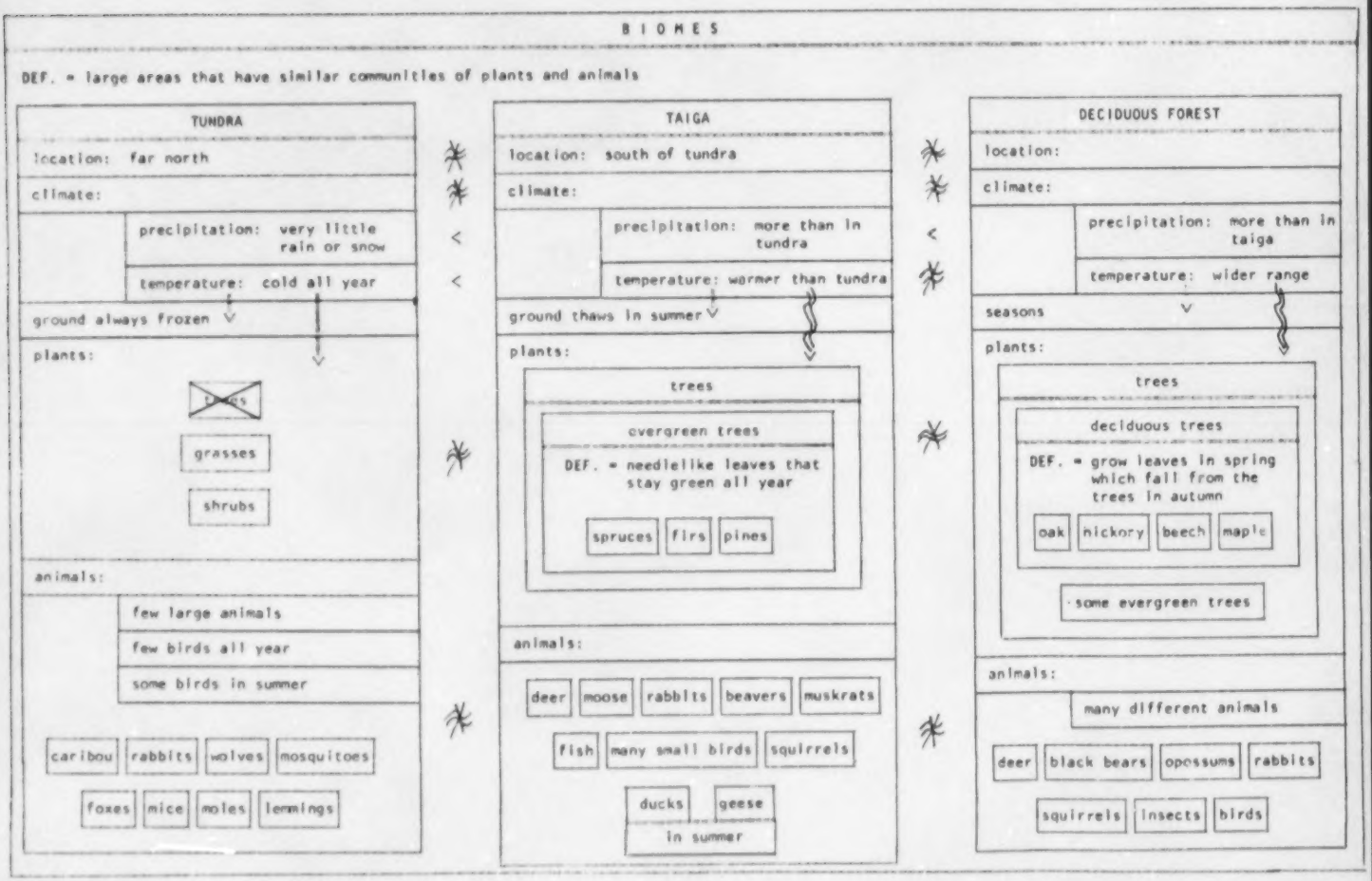
Figure 2. Examples of static frames.

Figure 3. Examples of "top-down" idea-mapping exercises.

Figure 4. Examples of a "bottom-up" idea-mapping exercise.

Figure 5. Examples of "bottom-up" idea-mapping exercises.

Figure 6. Example of a "bottom-up" idea-mapping exercise.


BIOMES
DEF. = large areas that have similar communities of plants and animals
TUNDRA
location: far north
climate:
precipitation: very little rain or snow
temperature: cold all year
ground always frozen
plants:
trees
grasses
shrubs
animals:
few large animals
few birds all year
some birds in summer
caribou
rabbits
wolves
mosquitoes
foxes
mice
moles
lemmings
TAIGA
location: south of tundra
climate:
precipitation: more than in tundra
temperature: warmer than tundra
ground thaws in summer
plants:
trees
evergreen trees
DEF. = needlelike leaves that stay green all year
spruces
firs
pines
animals:
deer
moose
rabbits
beavers
muskrats
fish
many small birds
squirrels
ducks
geese
in summer
DECIDUOUS FOREST
location:
climate:
precipitation: more than in taiga
temperature: wider range
seasons
plants:
trees
deciduous trees
DEF. = grow leaves in spring which fall from the trees in autumn
oak
hickory
beech
maple
some evergreen trees
animals:
many different animals
deer
black bears
opossums
rabbits
squirrels
insects
birds

CULTURES
Technology Tools, machines Food Clothing Shelter
Institutions Family Politics Economy Religion Education
Language
Arts

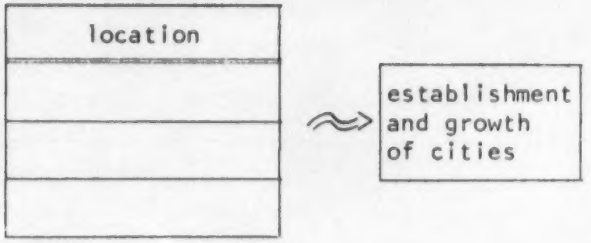
a. Frame for Cultures

SYSTEMS
Function/use
Parts and their functions
Explanation of how it works
Problem/solution

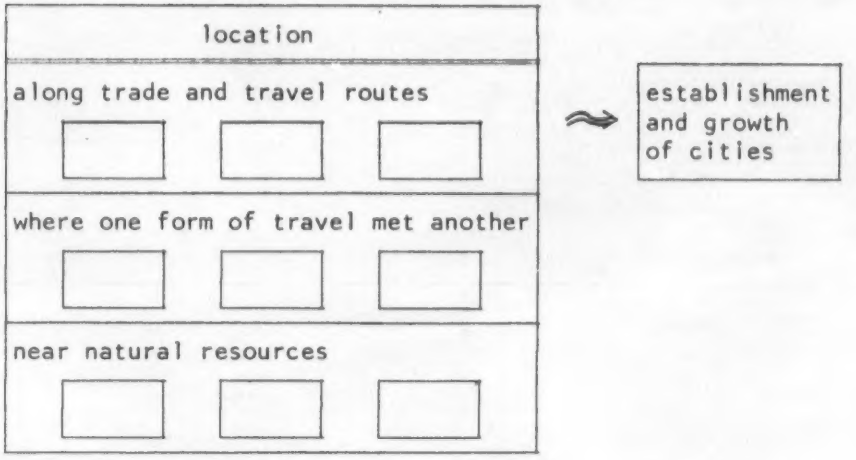
b. Frame for Systems (e.g., systems of the human body and technological systems such as the hydraulic brake system of an automobile)

WARS
Setting (date, place)
Participants on both sides
Causes
Major events (battles, etc.)
Key people
Resolution
Other outcomes/effects

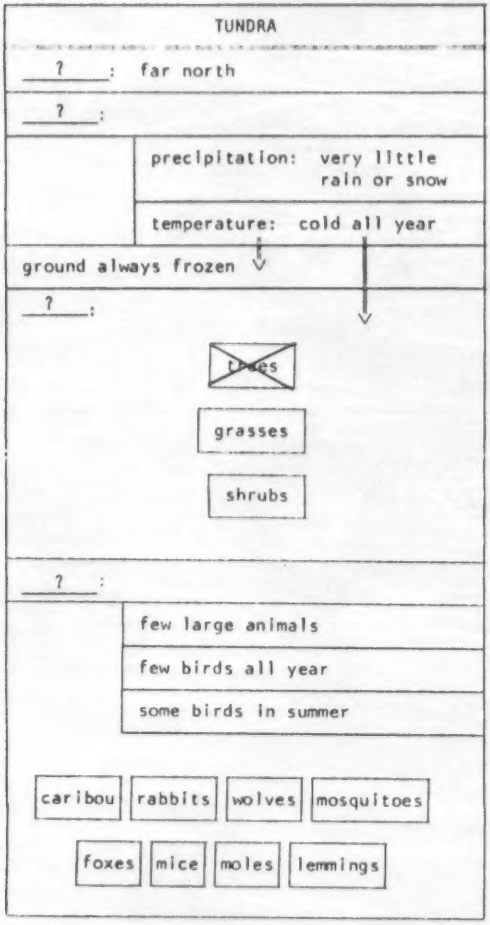
c. Frame for Wars

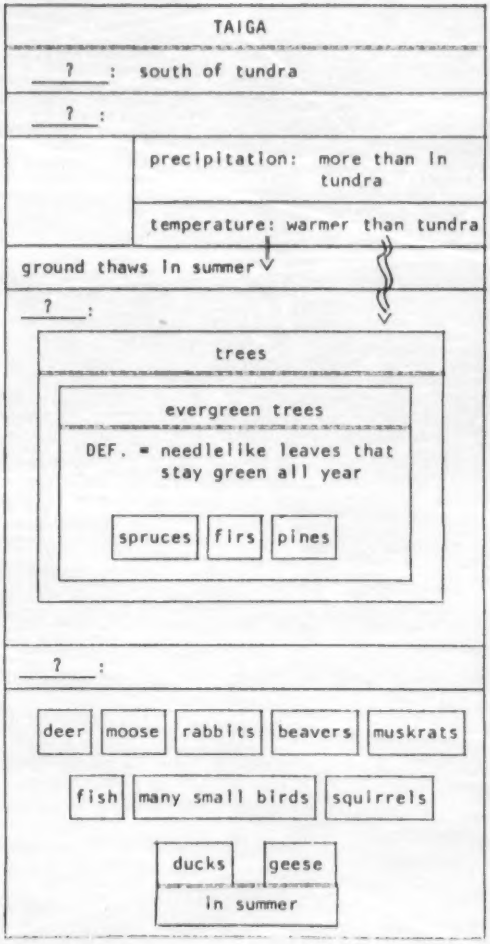


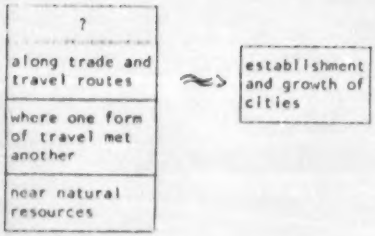
This exercise requires students to supply three major types of locations that influence the establishment and growth of cities, as presented in the text.


location
along trade and travel routes
where one form of travel met another
near natural resources
establishment and growth of cities

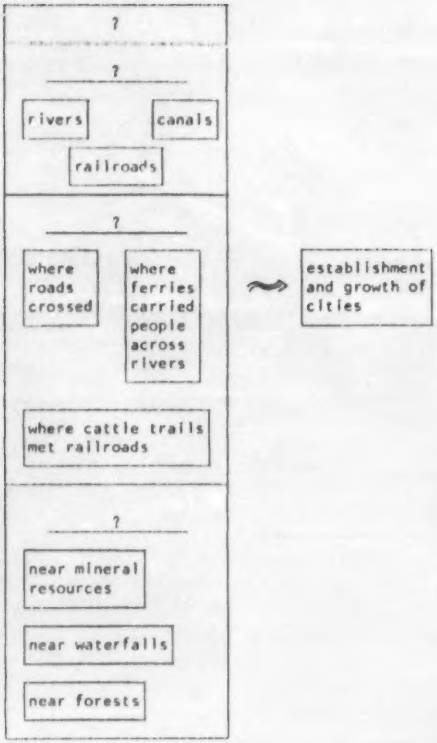
This exercise requires students to supply more detailed information--examples of the types of locations that influence the establishment and growth of cities.


TUNDRA
? : far north
? :
precipitation: very little rain or snow
temperature: cold all year
ground always frozen
? :
trees
grasses
shrubs
? :
few large animals
few birds all year
some birds in summer
caribou
rabbits
wolves
mosquitoes
foxes
mice
moles
lemmings


TAIGA
? : south of tundra
? :
precipitation: more than in tundra
temperature: warmer than tundra
ground thaws in summer
? :
trees
evergreen trees
DEF. = needlelike leaves that stay green all year
spruces
firs
pines
? :
deer
moose
rabbits
beavers
muskrats
fish
many small birds
squirrels
ducks
geese
in summer


?
along trade and travel routes
where one form of travel met another
near natural resources
establishment and growth of cities

This exercise requires students to find a superordinate term for three given examples.



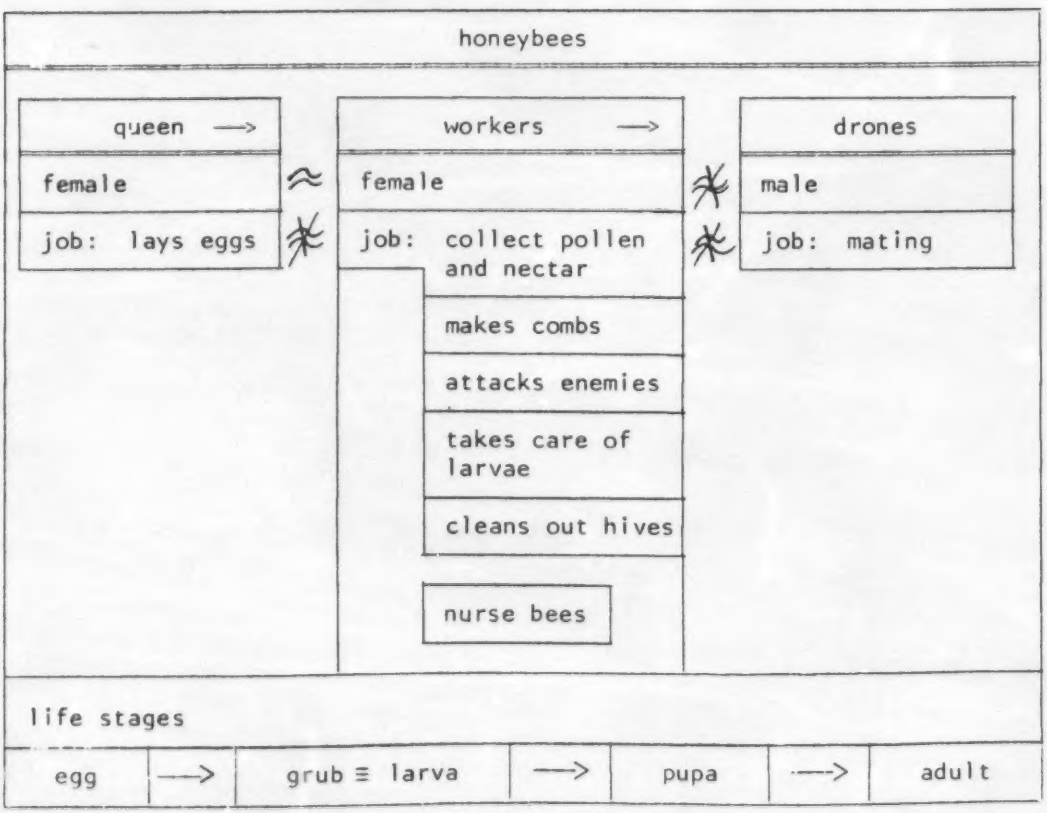
This exercise requires two levels of generalization: (a) one superordinate term each for examples in three categories, and (b) a superordinate term for the term generated in a.

This exercise requires student to induce the principle with minimal prompting.

Directions to Students: Make an i-map that uses all of the following terms from the chapter on honeybees.

jobs
female
life stages
collects pollen and nectar
honeybees
drone
queen
makes combs
male
pupa
lays eggs
mating
takes care of larvae
egg
worker
grub
adults
cleans out hive
larva
nurse bees
attacks enemies

Possible Student Response:



Appendix A

Large areas that have similar communities of plants and animals are called biomes. Nonliving things such as temperature and rainfall help determine what lives in a biome. The different types of biomes are tundra, taiga, deciduous forest, tropical rain forest, grassland, desert, and ocean.

Tundra

If you lived in the tundra biome, you would be in the far northern part of the world. It would be cold all year. You would need to dress warmly even in the summer. The temperatures are near freezing in the summer. There is usually very little rain or snow in the tundra.

You would not see any trees in the tundra. The ground is always frozen except for a top thin layer of soil during the summer. Also, plants grow only about two months out of the year in the tundra. For these reasons, the plant life is mostly grasses and shrubs.

You could expect to find few large animals in the tundra. Among the larger ones are caribou, rabbits, wolves, and foxes. There are many mosquitoes, mice, moles, and lemmings (LEM ingz). You would see some birds in the summer. Few birds live all year in the tundra.

Taiga

If you traveled south from the tundra, you would enter a biome called the taiga. Here, the yearly temperatures would be warmer than in the tundra. Also, there is more precipitation in the taiga.

The ground thaws in the summer because of the warmer temperatures, These warmer temperatures allow larger plants to grow. Most of the trees you would see in the taiga are evergreen trees. Evergreen trees have needlelike leaves that stay green all year. Some of the evergreen trees you would see are spruces, firs, and pines.

Anytime during the year, you might see deer, moose, rabbits, or squirrels. Streams and ponds are homes for beavers and muskrats and many kinds of fish. Many small birds live in the taiga. In the summer, you might see ducks and geese.

Deciduous Forest

Perhaps you live in a deciduous (dih SIJ uh wuhs) forest biome. If you do, you enjoy a wide range of yearly temperatures. This wide range of temperatures results in spring, summer, autumn, and winter seasons. The yearly precipitation is more here than in the taiga.

In this forest biome, you would notice many deciduous trees. Deciduous trees grow leaves in the spring which fall from the trees in autumn. Oak, hickory, beech, and maple are deciduous trees. You would also see many other kinds of plants. This biome may have some evergreen trees too.

You would see many different animals in this biome. Deer and black bears are examples of some of the larger ones. A few of the many smaller animals are opossums, squirrels, rabbits, birds, and insects. Name two other animals you might find living in this forest biome.

(Sund, Adams, & Hackett, 1980, pp. 139-142)

Appendix B

More Cities Grow

Rivers, such as the Ohio, were used by westward bound settlers. Settlements were located on river banks to serve the needs of river travelers and those who chose to settle in the region. When the steamboat was invented, river traffic increased. People moved and settled on farms and ranches. Food and other products of the West were shipped east. Goods manufactured in eastern factories were shipped west. River towns were important in this trading. Many grew into major cities, such as Cincinnati, Ohio; Louisville, Kentucky; Memphis, Tennessee; and Kansas City, Missouri. Locate other cities that grew up on rivers on the map of the United States on pages 92-93.

People and goods moved east and west by canal (kə nal'). A canal is a waterway that is built to connect two bodies of water. Towns were established along canals just as they were along rivers.

A few roads were built. Inns were started along these roads to serve the needs of travelers. Towns were begun where roads crossed, or where ferries carried travelers across rivers. Sometimes cities grew up at places where one form of travel met another.

After the Civil War, railroad building increased. Many cities were started to serve the needs of railroad workers and travelers. As the rails stretched west, so did urban, or city, growth. Western farmers and ranchers sent food and cattle to eastern markets. Cities grew where cattle trails met railroads. Some river cities became important railroad

cities. Chicago, Illinois; St. Paul, Minnesota; and Omaha, Nebraska, grew rapidly after the railroads were built. No longer were large cities to be found only on the coasts.

Some cities grew because of their natural surroundings. Mining towns started near places rich in minerals. Factory towns were built near waterfalls. Lumber towns began near forests.

(King, Dennis, & Potter, 1982, p. 126-127)

Appendix C

Honeybees are a common example of social insects. If you were to watch honeybees closely in their home, or hive, here is what you might see and learn.

The hive might be located in a hollow tree. Or it might be found in a box especially constructed by someone for this purpose. Whatever the location of the hive, you would find sheets of wax hanging from the top and sides. (In hand-made hives, special wooden frames are built to hold the wax.) You would find bees busy making the sheets of wax and turning them into combs. You probably have already seen these combs. They are built of hundreds of six sided cells. Bees use the cells to store honey for their own use.

Suppose you watched the bees that were making the honeycomb. You would find that they scraped the wax off the surfaces of the abdomens with their hind legs. The wax is secreted by glands on the abdomen.

You would also observe other bees streaming into the hive and then releasing a fluid into the completed cells of the comb. If you tasted this fluid, you would find that it was sweet and that it had a flowerlike odor. This fluid is flower nectar. The bees suck it up through their tubelike mouth parts from the bases of flower petals. The nectar is then swallowed. But it passes only into the first section of the stomach, the honey stomach. Here digestive juices change the sugars of the nectar into a simpler kind of sugar and other substances are added. It is then deposited into the cells of the comb. Now it is what we know and eat as honey.

By glancing around at the many cells of the comb, you would notice that not all cells were being filled with honey. Many cells would contain what might look like a short, fat, white worm, called a grub. This grub is the larva, or infant state, of the bee. You recall that an infant grasshopper resembles an adult grasshopper. However, the infant bees do not look at all like adult bees.

Some bees function as nurses to tend and feed the larvae. For the first few days after an egg hatches into one of the eyeless, legless larvae, it is fed a kind of milk that the nurse bees secrete from glands in their heads. After the period of milk feeding, most of the larvae are fed a combination of honey and pollen, which the bees also collect from flowers.

A few of the larvae are fed solely on what is called "royal jelly." This feeding difference makes an amazing difference in the ways in which the larvae develop. Those larvae fed on honey and pollen develop into worker bees (always females) or into males, which are called drones. Although the worker bees are females, they cannot produce eggs. Their egg-laying structures become modified into stingers. Those female larvae fed nothing but royal jelly develop into females called queen bees. The queens have both egg-laying structures and slender stingers.

About six days after the larvae first appear, they have grown so large that each almost fills its entire cell. The nurse bees now build a wax cap over each cell. At this time important changes take place as the larva lies quietly in its cell. This stage is called the pupa (pyo͞o'pə) stage. Then, after twelve days to two weeks (depending upon whether the pupa will become a worker, a drone, or a queen), the adult

bee breaks out of the cell. During this short time an amazing change has taken place. The wormlike larva has changed into a bee with wings, chewing and sucking mouth parts, two large complex eyes, three simple eyes, two pairs of delicate wings, and six legs.

If you kept track of the adults breaking out of their cells, you would find interesting differences in the jobs of the workers, drones, and queens. The workers (remember, these are modified females) do all of the work of the hive. They collect pollen and nectar. They make the combs. They take care of the larvae. They clean out the hive. They swarm out to attack enemies with their stingers. They do everything but lay the eggs. Laying the eggs is the job of the queen.

Workers are produced constantly during warm weather. Queens are produced only when the hive beings to be overcrowded. When that occurs, nurse bees feed only royal jelly to some of the larvae in order to produce queens.

The first queen that breaks out of its cell flies out into the air and mates with one of the drones (males). Then she returns to the hive to become the new queen. In the meantime, the workers destroy the surplus queens.

However, about a week before the new queen breaks out of her cell, the old queen leaves the hive with about half of the workers. They fly off in a cloud in what is called swarming. They establish a new hive in a suitable place, such as a hollow tree or a large crack in a rock, and start a new community.

The new queen devotes her life to one job alone--egg laying. She may live from three to five years. During that time she may lay over a million eggs. Workers tend her carefully. They feed her, stroke her, and build special cells in which she deposits her eggs.

Drones do almost nothing. However, the drones are necessary, of course, to mate with the queen. Only one drone mates with the queen. Her body stores throughout her life-time the many millions of sperms that he deposits. The sperms fertilize the eggs laid during the long life of the queen. The fertilized eggs produce both workers and queens. Occasionally the queen lays unfertilized eggs; these develop into drones. After the mating flight and toward the middle of summer, the workers chase out of the hive, or kill, most of the drones. The drones have done the one job they are capable of doing. They are no longer needed for the survival of the community.

(Brandwein, Yasso, & Brovey, 1980, pp. 338-340)